

EVALUATION OF SEEPAGE DURING THE THERMAL PERIOD AT YUCCA MOUNTAIN

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RESEARCH OBJECTIVES

Predicting the amount of water that may seep into waste emplacement tunnels (drifts) is essential for assessing the performance of the geologic nuclear waste repository at Yucca Mountain, Nevada. At ambient temperatures, seepage from the unsaturated fractured tuff into the drifts is reduced by the capillary barrier behavior at the rock-drift interface. In addition, the fractured rock in the drift vicinity will be heated to maximum temperatures of more than 130°C, caused by the radioactive decay of the nuclear waste, and water percolating down towards the repository will be subject to vigorous boiling during the first several hundred years following waste emplacement. Thus, the superheated fractured rock forms a vaporization barrier that may further limit the potential for seepage. To study the impact of the drift-scale thermal-hydrological (TH) perturbations, a TOUGH2 simulation model was developed for the prediction of “thermal seepage” (i.e., seepage during the time that flow is perturbed due to heating).

APPROACH

The future TH conditions in the vicinity of waste emplacement drifts at Yucca Mountain are evaluated with a heterogeneous dual-permeability process model. The conceptual framework for describing the TH processes is based on models that accurately represent the thermal response of large *in situ* heater tests. The specific simulation framework for seepage is consistent with the modeling method employed in ambient seepage studies, which was developed based on model comparisons with liquid-release seepage testing. The key elements in this method—small-scale fracture permeability heterogeneity, relatively weak capillary strength, and the effect of discrete fractures at the drift wall—have all been included in the thermal seepage model. Several simulation cases are performed that cover the expected range of TH conditions at Yucca Mountain. Transient seepage rates during the period of enhanced temperatures are directly calculated from the model and compared to the respective seepage rates at ambient conditions.

ACCOMPLISHMENTS

Simulation results demonstrate that the thermal perturbation of the flow field—giving rise to increased downward flux from the condensation zone towards the drifts—is strongest during the first few hundred years

after waste emplacement, corresponding to the period when rock temperature is highest and the vaporization barrier is most effective (Birkholzer et al., 2003). Even for high percolation fluxes into the model domain, and strong flow channeling as a result

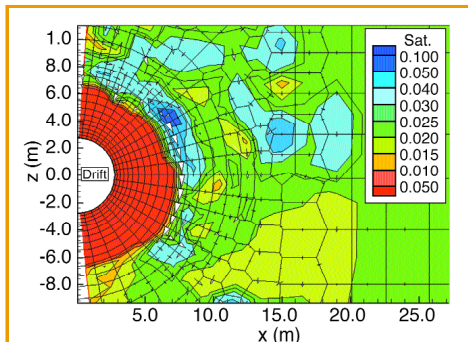


Figure 1. Fracture saturation and liquid flux vectors for a selected simulation case at 100 years of heating

of fracture heterogeneity, water is not predicted to penetrate far into the superheated rock during the time that rock temperature is above boiling, and model results show no seepage (Figure 1). At the time when temperature has returned to below-boiling conditions and fractures start rewetting at the drift, the capillary barrier at the drift wall continues to reduce (or prevent) water seepage into the drift. Seepage is predicted to occur for such simulation cases that feature strongly heterogeneous fracture permeability fields, weak fracture capillary strength in the drift vicinity, and high percolation fluxes. In these cases, water starts to seep several

hundred to a few thousand years after the rock temperature has returned to below boiling, the delay caused by the slow saturation buildup in fractures. Seepage amounts increase with time and asymptotically approach seepage rates estimated for long-term ambient conditions.

SIGNIFICANCE OF FINDINGS

The model results consistently demonstrate that (1) seepage does not occur under above-boiling conditions near the drifts, and (2) seepage under below-boiling conditions does not exceed the amount of ambient seepage. These findings are very important for the performance of the nuclear waste repository; they are currently being implemented into the performance assessment supporting the license application process.

RELATED PUBLICATION

Birkholzer, J., S. Mukhopadhyay, and Y.W. Tsang, Modeling water seepage into heated waste emplacement drifts at Yucca Mountain. Proceedings of the TOUGH Symposium 2003, Berkeley, California, May 12–14, 2003.

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